

A STUDY OF THE ASTRAGALUS. By R. B. SEYMOUR
SEWELL, B.A., *Christ's College, Cambridge, Fellow of the
Anthropological Institute.* (PLATES XXXVII.-XLIH.)

PART II.

The Os trigonum.—So much has been written by previous observers about this little ossicle, that very little remains to be said.

With regard to its frequency of occurrence, different observers have obtained very different results.

Stieda (16), who examined a series of 305 astragali, found eighteen cases, thus getting a percentage of 5·9 per cent.

Thomson (18), from the collected observations of the Anatomical Society of Great Britain and Ireland, obtained the following figures:—

Number of astragali examined, 438.
Evidence of separation in 18 = 4·0 %.

Pftzner in his paper (13) divides the bones that he examined into four separate series, as follows:—

SERIES I.	{ Number of bones examined, }	128.	Evidence of separation in	{ 8 = 6·3 %.
SERIES II.	„	378.	„	29 = 7·7 %.
SERIES III.	„	150.	„	9 = 6·0 %.
SERIES IV.	„	185.	„	5 = 2·7 %.

In this way he arrived at a mean percentage of 6·1 per cent.

In the series of Egyptian bones which I have examined, amounting to 1006 specimens, evidence of separation was found to be present in 110 cases, or in a percentage of 10·9 per cent.

Besides these 110 specimens, I have also been able to examine a separate series of 31 astragali, which possessed separate ossa trigona, thus raising the number of examples to 141.

Evidence of Separation.—The amount of evidence presented

by individual bones varied to such a large extent that I divided the specimens into four groups according to the extent of the evidence presented:—

1. Those bones in which the os trigonum is completely fused with the tuberculum laterale, the original separation being merely indicated by a sharp notch in the margin of the processus posterior. This type of evidence was present in 85 specimens out of 141; that is to say, in 60·3 per cent. of the bones which possessed 'Ossa trigona.'

2. Those bones in which the os trigonum is fused with the tuberculum laterale; the only evidence of their originally separate origins being a groove on the under articular surface, which separates the facies articularis calcanea posterior into a pars propria and a pars trigona.

This evidence is much more rarely found than the preceding type; I have only succeeded in obtaining 7 specimens which presented it, so that it only occurs in 5 per cent. of the specimens.

3. Those bones in which fusion of the os trigonum and tuberculum laterale was more or less incomplete, the two bones being separated by well-marked notches and grooves on the surface of the processus posterior.

This type of evidence was presented by 15 specimens, or by a percentage of 10·6 per cent.

4. Those bones in which the os trigonum remained completely separate from the rest of the astragalus.

The number of bones in which this occurred amounted to 34, or a percentage of 24·1 per cent.

As Pfitzner has pointed out, we can in this class distinguish two different varieties in the manner of attachment of the os trigonum to the corpus tali: firstly, the os trigonum may remain connected with the corpus by means of fibrous tissue, in which case the area of attachment on the talus is rough (fig. 9); or secondly, the opposed surfaces of the bones may be covered with a thin layer of hyaline cartilage and separated by a joint cavity which may be continuous with the cavity of the posterior talo-calcaneal articulation.

General Shape and Size.—Bardleben (2) describes a well-formed os trigonum as possessing four surfaces—an *inferior*, which looks towards the os calcis, an *anterior*, which looks

towards the astragalus, and two *superior* surfaces, a medial and a lateral. We may also distinguish four angles—an upper, an hinder, a lateral, and a medial.

The two upper or superior surfaces are usually not well marked off from each other, but form a roughened surface, which is concave both in the antero-posterior and transverse directions.

The anterior surface may also vary, in some cases being smooth for articulation with the talus, and in others, as Bianchi has pointed out, it may be roughened and present a sponge-like appearance; in these cases the ossicle is attached to the astragalus by fibrous tissue. The inferior surface is smooth in a well-developed specimen, and forms an articulation with the calcaneum, the articular surface sloping somewhat downwards and backwards, and makes an angle with the *facies articularis calcanea posterior* of the *corpus tali*. As Bennett (4) has pointed out, the calcaneum presents a corresponding articular surface, and this can only be the result of mutual pressure *ab initio*.

With regard to size, a well-formed and well-developed trigonum measures 15-22 mm. in a transverse direction, and 10-15 mm. in both the sagittal and vertical directions. One of the largest specimens recorded is that described by Bianchi (5), in which the bone measured 19 mm. in its maximum longitudinal diameter, 11 mm. in its transverse diameter, and 14 mm. in its vertical diameter. Pfitzner (13) also records a case in which the maximum transverse measurement was as much as 24 mm.

As in all inconstant parts of the skeleton, so also in this case, the general form of the ossicle varies very much in different specimens, and in some cases the bone may be quite abortive and be represented by merely a small nodule of bone attached to the *processus posterior*.

Pfitzner also notes two cases in which the *os trigonum* was subdivided into two equal parts, and in two other cases it was divided into two unequal parts, while in one specimen the ossicle was represented by a number of small irregular nodules of bone; this latter case, however, he regards as being probably due to pathological causes.

Position of Os trigonum.—In the great majority of cases in which this ossicle is present its position is very fairly constant. It lies external and somewhat posterior to the tuberculum laterale, and, according to Pfitzner, never forms the whole processus posterior, and never takes any part in the formation of the sulcus musculi flexoris hallucis longi; to quote his own words, "Ich behaupte, dass, wenigstens soweit ich gesehen, das Trigonum niemals an der Rinne theilnimmt und deshalb auch niemals das ganze Tuberculum laterale umfasst."

This is certainly true for the great majority of cases (*vide* Pls. XXXVIII. and XXXIX.), but in very rare cases we find that the os trigonum does project on the medial side of the tuberculum laterale, and consequently assists in the formation of the flexor groove. Such a condition occurs in No. 528 (Pl. XXXVII. fig. 12). We may also in rare cases find a specimen in which the ossicle does not merely assist in the formation of the groove, but gives rise, not only to the whole groove, but also to by far the greater part of the tuberculum mediale.

In two specimens, Nos. 601, 942, the posterior aspect of the bone was almost entirely occupied by a rough surface for the attachment of an epiphysis (Pl. XL. fig. 13 and Pl. XXXIX. No. 6). This epiphysis was, I take it, the os trigonum, but unfortunately it had become separated and was lost in both cases.

To the outer side of this roughened area was a small pointed triangular process—the tuberculum laterale.

The roughened area looked backwards, outwards, and slightly downwards in the natural position of the bone; it was of a more or less oval form, and extended from the small tuberculum laterale above mentioned almost to the circular area on the medial aspect of the corpus tali, which gives attachment to the deep portion of the ligamentum deltoideum. In the larger of the bones, No. 601, it measured 16 mm. in length and 9 mm. in breadth at its widest part; while in the smaller specimen, No. 942, it was 14 mm. in length and 10 mm. in breadth.

We may also in certain cases find that the trigonum is in a very abortive condition, and in such cases it frequently loses its normal connections with the tuberculum laterale, and becomes attached to various parts of the process, most

commonly to the superior surface, where it forms a small bony nodule (Pl. XXXVIII. No. 6).

The Origin of the Os trigonum.—Gruber (10) was the first to point out that this ossicle may arise in two ways; firstly as an ossification in ligament, or as a constant or inconstant epiphysis, which may remain more or less separate.

Bardeleben (3) later showed that in the second month of foetal life the os trigonum is represented by a separate cartilage. In the adult, however, as we have already seen, evidence of separation can only be detected in about 10 per cent. of the specimens.

The disappearance of all traces of the ossicle in by far the greater majority of cases may, as Pfitzner has pointed out, be due to two causes:—

Firstly, to the abortion and ultimate disappearance of the cartilaginous rudiment, as Thilenius (17) has shown an exactly similar process may occur in the case of the intermedium antebrachii (*i.e.*, the semilunar); and *secondly*, to the complete fusion of the cartilaginous or bony nodule with the rest of the corpus tali. As we have already seen, we can frequently find slight traces of the original separation of these two constituents, and the last vestiges of their connection are to be seen either on the under surface or on the lateral edge of the bone; on the under surface we may get a groove (*vide supra*), and on the lateral edge a small notch.

Besides this mode of origin from a separate cartilaginous formation, we may, perhaps, get an os trigonum being formed by a fracture of the processus posterior.

The theory that the os trigonum was caused by a fracture was first put forward by Cloquet (7) in 1844; and Shepherd (14) in 1883 described the os trigonum and attributed it to a fracture caused by a sudden strain on the ligamentum talo-fibulare posterius; but this idea was at the time scouted by the majority of anatomists.

Bennett (4) has also considered this question, and he concludes that the os trigonum arises as a separate ossicle, but may become detached from its original position by a sudden strain of the ligamentum talo-fibulare posterius, and may acquire a fresh union with the corpus tali. In a case that he describes

"the ossicle has been displaced backwards from the astragalus except at the very innermost limit of the inferior articular surface. Here osseous union seems to have occurred in consequence of the fragments having been maintained in contact by the sheath of the flexor hallucis tendon."

Mansell Moullin (11), in an article on the os trigonum, quotes from a paper by Vollbrecht of Breslau, in which two cases of fracture of the tuberculum laterale are described; the first being due to traction of the ligamentum talo-fibulare posterius, and the second being due to pressure against the calcaneum. In both cases subsequent reunion of the astragalus and the detached piece of bone took place.

From this evidence we must conclude that the processus posterior may become fractured and subsequently give rise to an ossicle, which we may designate by the term 'os trigonum secundarium,' to distinguish it from the ossicle, formed by the development of a special cartilaginous nodule, that subsequently becomes ossified, and to which we may give the title of 'os trigonum proprium.'

The tuberculum mediale bounds the sulcus musculi flexoris hallucis longi on its inner and anterior side; it is smaller and less prominent than the tuberculum laterale, and is of a more rounded form.

It varies very much in size, and in some bones is quite small and insignificant. This lack of development reached its climax in two bones (Nos. 435, 753) in which there was no separate projection of the tuberculum mediale — the inner or medial aspect passing continuously into the posterior surface, which consisted of a more or less rounded mass of bone without any distinction into tubercula mediale and laterale, and with a total absence of any flexor groove (Pl. XL. fig. 14).

The tuberculum mediale is in nearly every case developed from the corpus tali; as we have already seen, however, it may, in very rare cases, be formed by the os trigonum.

The surface of this tuberosity is roughened to a greater or less extent, and serves for the attachment of several ligamentous bands.

Attached to the medial aspect of the tubercle, and running almost horizontally to the posterior margin of the sustenta-

culum tali of the calcaneum, is a narrow ligamentous band, the ligamentum talo-calcaneum mediale.

According to Barclay Smith (1), another set of fibres gains its attachment to the talus at the same point, and runs downwards and backwards to be inserted into the calcaneum just behind the sustentaculum; this band serves to complete the floor of the groove for the musculus flexoris hallucis longi.

The *sulcus musculi flexoris hallucis longi* runs from above downwards and inwards, and at the same time curves round anteriorly so as to reach the ventral aspect of the corpus. It varies very much in depth according to the degree of development of the tubercula mediale et laterale, which form its inner and outer boundaries, and, as we noted above, may be absent altogether.

The groove varies very much in the direction in which it traverses the posterior aspect of the corpus. On the average, the sulcus runs downwards at an angle of 149° with the perpendicular; but in Nos. 167, 937 the angle was as little as 133° , while in No. 788 it was only 132° . On the other hand, however, in No. 196 the angle was as great as 175° .

The Inferior Surface.—This surface is mainly occupied by the large facies articularis calcanea posterior (Pl. XLI. fig. 15).

To the inner or medial side is situated the tuberculum mediale or internal tuberosity; this surface of the tubercle may vary very much in size.

Externally, the tuberosity is separated off from the facet in a greater or lesser degree by the groove for the tendon of the flexor longus hallucis muscle. Occasionally this tuberosity is large and is very much flattened, and in extreme cases a special facet is developed on it; this is known as the *facies inferior accessoria corporis tali*.

In a well-developed specimen this is found to be situated partly on the under surface of the tuberculum mediale, and partly on the smooth ridge which runs forwards from this to the facies articularis calcanea media, on the under surface of the neck, and which closes in the sulcus tali at its medial end.

When this facet is present, the sulcus appears to fork at its internal end, the anterior arm passing in front of the facet,

separating it off from the *facies articularis calcanea media*, while the posterior arm passes behind and somewhat laterally and separates it from the *facies articularis calcanea posterior*. The exact position of the facet seems to vary slightly in different bones; in some it is situated entirely on the *tuberculum mediale*, while in others it may be further forward on the above-mentioned ridge (Pl. XLI. fig. 16).

It articulates with a separate facet on the calcaneum.

Its occurrence seems to be comparatively rare. Pfitzner apparently did not find a single instance, but in the bones I have examined I have found six specimens, which thus give a percentage of .6 per cent. (Nos. 191, 216, 248, 456, 711, 904).

The facies articularis calcanea posterior.—This varies very much in shape in different specimens, but it is generally of a more or less oval or quadrilateral type.

Its long axis runs forwards and outwards, making an angle of 45° (approx.) with the antero-posterior axis of the bone.

The facet presents a very well-marked concavity in the direction of its long axis; the degree of curvature varies, however, in different specimens, but as a general rule is much greater in bones of a small size.

In the direction at right angles to this the facet is usually flat or only very slightly concave.

The antero-medial border of the facet is usually sharply marked off from the *tuberculum mediale*, but in about 1.4 per cent. of the bones this distinction does not exist, and the facet is continued on to the surface of the *tuberculum* (Nos. 101, 168, 193, 235, 272, 289, 338, 386, 425, 604, 615, 734, 811, 882).

As a further outcome of this condition, one finds rare cases in which the *facies articularis calcanea posterior* has apparently fused with the *facies inferior accessoria corporis tali*, giving rise to one large facet, which extends forwards along the *tuberculum mediale* (Pl. XLII. fig. 17). In such a facet, which is undoubtedly formed by the fusion of two separate articular surfaces, we must recognise a large posteriorly situated 'pars propria' and a smaller antero-medial 'pars accessoria'—this latter portion of the facet may extend forward along the ridge limiting the *sulcus tali*, and come into close contact with the *facies articularis calcanea media*.

Such a condition occurs in about 1 per cent. of the bones I have examined (Nos. 171, 307, 566, 637, 676, 720, 807, 877, 974, 975), and in two cases (Nos. 544, 932), this facet was fused with the *facies articularis calcanea media*, forming a single articular surface running along the whole undersurface of the bone.

Another form of variation, which is occasionally met with in this facet, is that in which the anterior border is prolonged forwards so as to overhang and considerably narrow the sulcus tali; and this condition may be developed to such an extent that the sulcus is almost entirely obliterated by a ridge of bone, along which the *facies articulares calcaneæ media et posterior* are continued, so that they come to touch one another and may even fuse, thus giving rise to a single long facet (Pl. XLII. fig. 18 and Pl. XLIII. fig. 19).

This condition must not be confused with that mentioned just previously, in which the facets meet along the *tuberculum mediale*. It is a much rarer condition, and I have only succeeded in finding one specimen in which the two facets meet (No. 466), and one in which they are fused (No. 655).

The *facies articularis calcanea posterior* is frequently more or less bevelled off at its antero-external border, and occasionally this condition is so marked that it gives rise to a separate facet for the calcaneum, to which I have given the name—

Facies externa accessoria corporis tali.—This is situated at the junction of the external surface of the corpus with the posterior wall of the sinus tali, in front and somewhat to the outer side of the *processus lateralis tali* (Pl. XLIII. fig. 20).

In a well-developed example it is of a more or less triangular shape, and we can distinguish an anterior and an external border, while inferiorly the facet becomes continuous with the *facies articularis calcanea posterior*. The articular surface looks downwards, forwards, and slightly outwards.

In the bones which I have examined, it was found to occur in 102 cases, thus giving a percentage of 10·15 per cent. (Nos. 1, 9, 16, 39, 44, 45, 53, 88, 90, 115, 120, 122, 125, 127, 130, 150, 156, 163, 164, 168, 172, 195, 197, 200, 201, 220, 240, 253, 262, 281, 287, 292, 306, 320, 325, 327, 337, 359, 362, 374, 403, 404,

408, 420, 426, 446, 477, 480, 482, 494, 495, 524, 528, 529, 548, 568, 594, 600, 610, 633, 661, 685, 701, 705, 712, 731, 734, 736, 737, 751, 753, 756, 758, 772, 775, 778, 796, 818, 831, 840, 841, 865, 866, 872, 879, 894, 897, 898, 905, 906, 919, 926, 934, 944, 955, 959, 960, 964, 971; and in Nos. 1, 9, 31, of the series with 'osa trigona.')

So far as I know, this facet has never been described before, in spite of the fact that it seems to be of comparatively frequent occurrence.

In almost all the bones in which this facet is present we find that the auricular facet (*facies malleolaris interna*) is prolonged forwards on the neck, and in 20 per cent. of the cases a distinct internal facet was present on the upper surface of the neck.

In only three specimens (Nos. 115, 403, 529) was this facet found to be present unaccompanied by a forward prolongation of the *facies malleolaris interna*.

I have also found indications of this facet to be present in the astragali of the anthropoid apes, in which, as I have already mentioned, the forward prolongation of the auricular facet is of frequent occurrence.

	No. of bones examined.	Facet present.	Facet doubtful.
Gorilla	7	3	2
Chimpanzee . .	6	4	—
Orang utan . .	15	11	—
Gibbon	8	6	—

From the consideration of the above facts, I have come to the conclusion that both the presence of this facet and the forward prolongation of the *facies malleolaris interna* are to be attributed to the influence of the same factors, namely, the constant dorsi-flexion and inversion of the ankle-joint in the sartorial position.

In this position the tibia presses on the neck of the astragalus, and this pressure is transmitted on to the bone below; the astragalus thus becomes forced down on to the calcaneum, and this gives rise to the *facies externa accessoria corporis tali*.

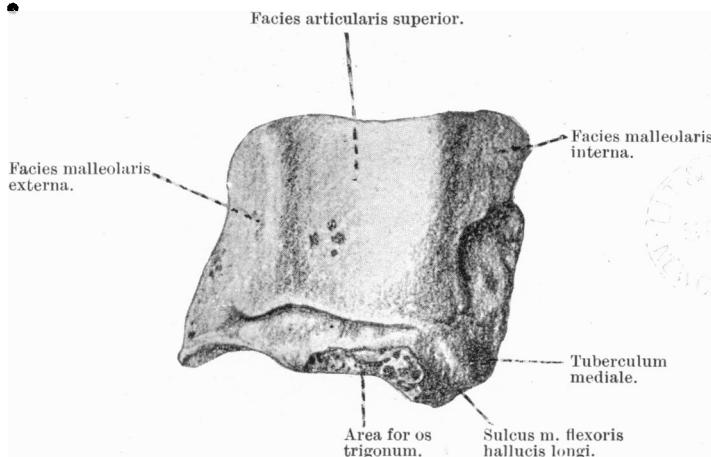


FIG. 9.—Norma posterior—showing area for attachment of os trigonum. No. 265.

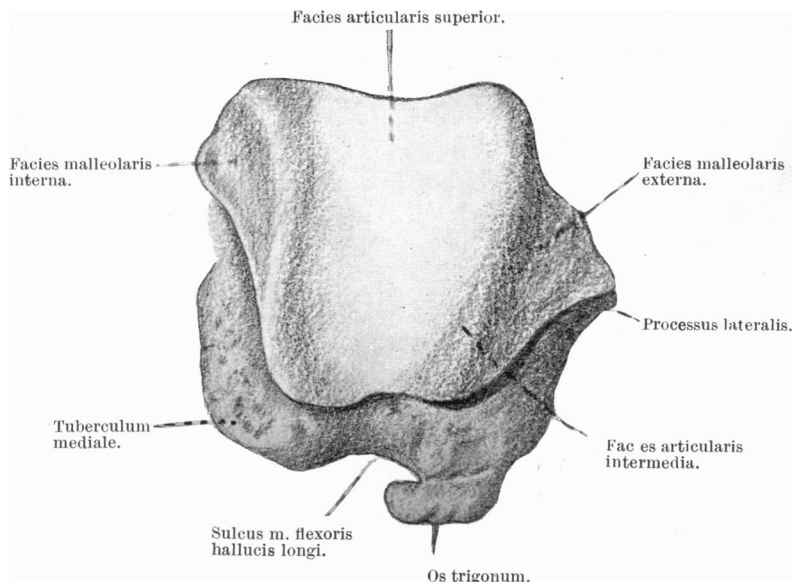


FIG. 12.—Norma posterior—showing a rare position of the os trigonum. No. 528.

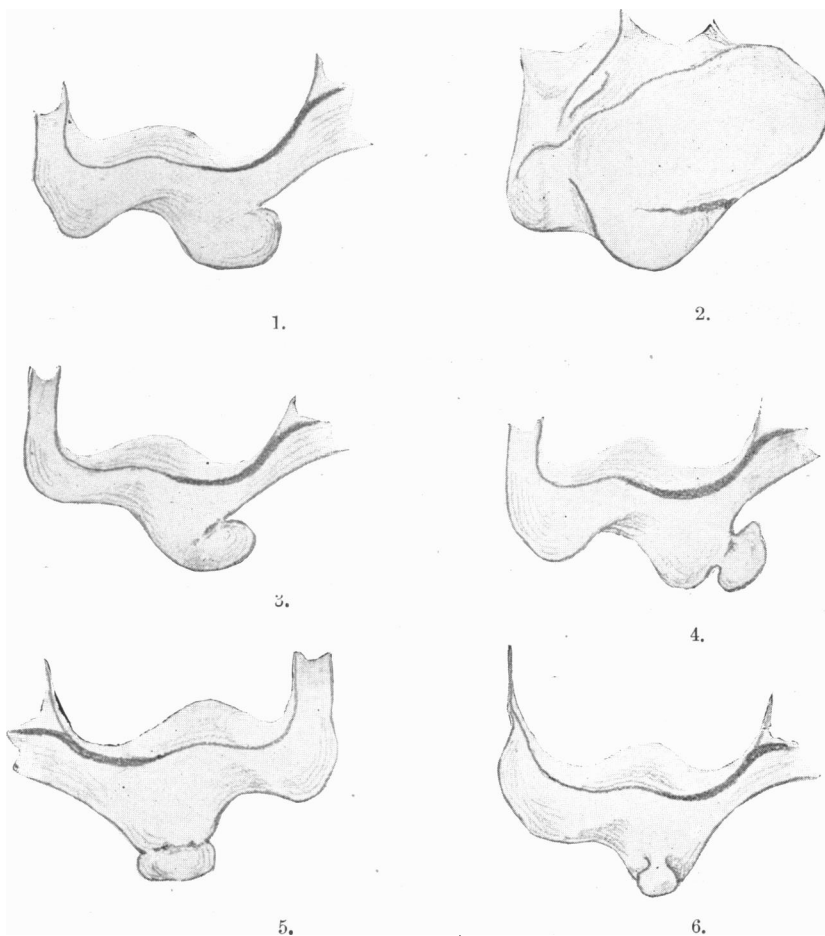


FIG. 10. —Diagrams showing varying types of os trigonum.

1. Almost complete fusion. No. 36.
2. Fused, except along groove on inf. aspect. No. 614.
3. Incomplete fusion. No. 603.
4. Still less complete fusion. No. 70.
5. Incomplete fusion. No. 82.
6. Incomplete fusion—os trigonum abortive. No. 999.

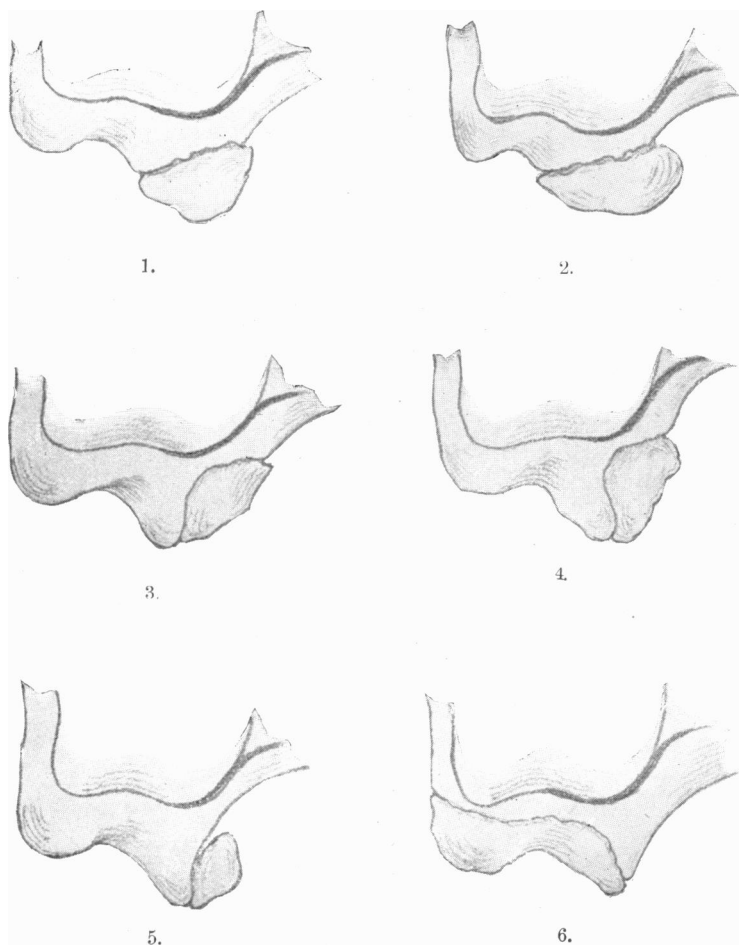


FIG. 11. — Diagrams showing varying types of os trigonum.

1. Large os trigonum, incomplete fusion. No. 614.
2. " " " " separate. No. 896.
3. Os trigonum separate. No. 809.
4. Talus and os trigonum separate. No. 997.
5. " " " " " " No. 361.
6. Os trigonum very large and separate, forming both tubercles. No. 601.

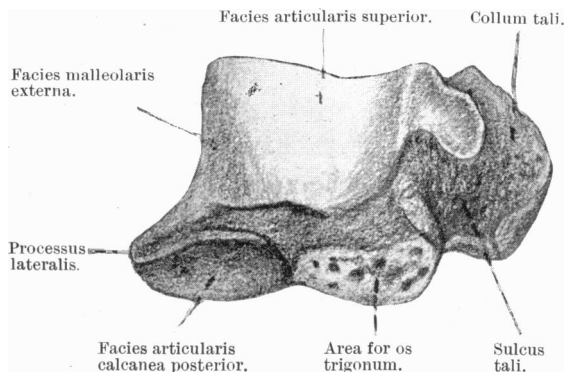


FIG. 13.—Norma posterior—showing large area for attachment of epiphysis, occupying almost whole of post. aspect. No. 942.

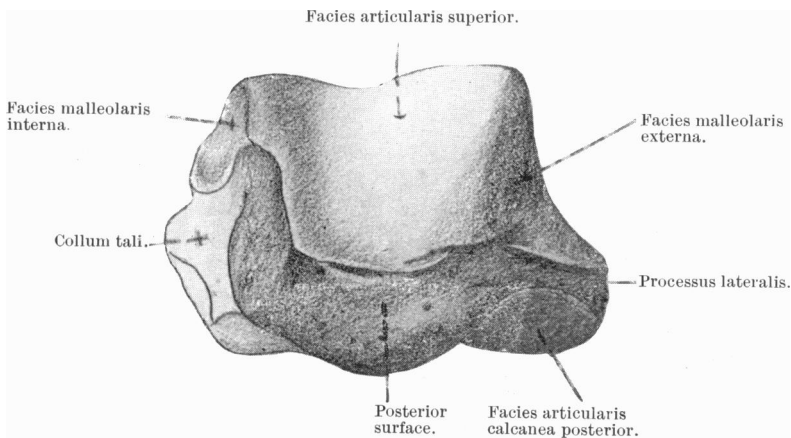


FIG. 14.—Norma posterior—posterior surface forming a rounded projection without distinct tubercles or flexor groove. No. 435.

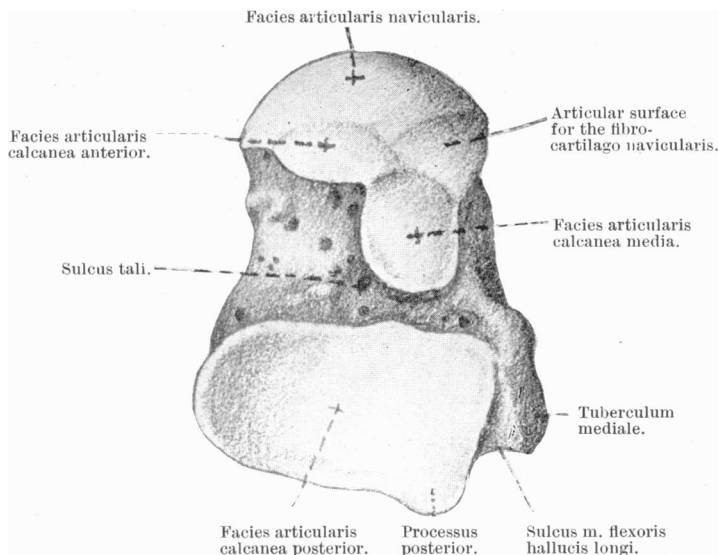


FIG. 15.—Norma basilaris—normal bone.

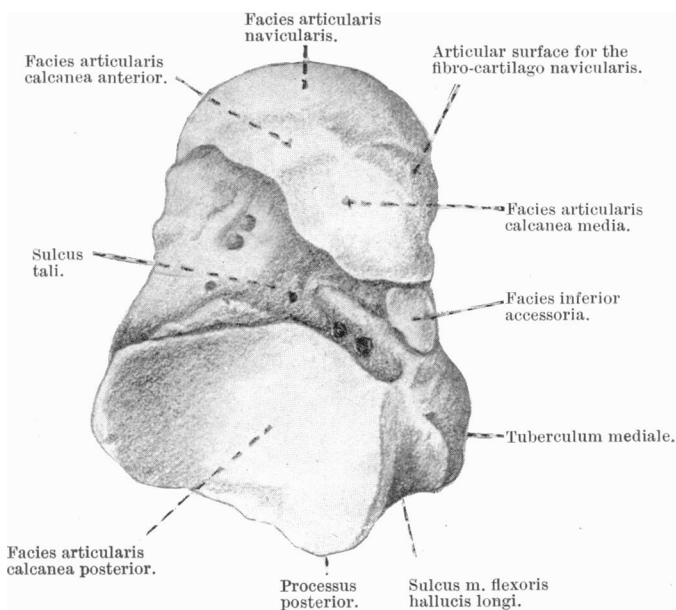


FIG. 16.—Norma basilaris—showing the presence of a facies inferior accessoria corporis tali.

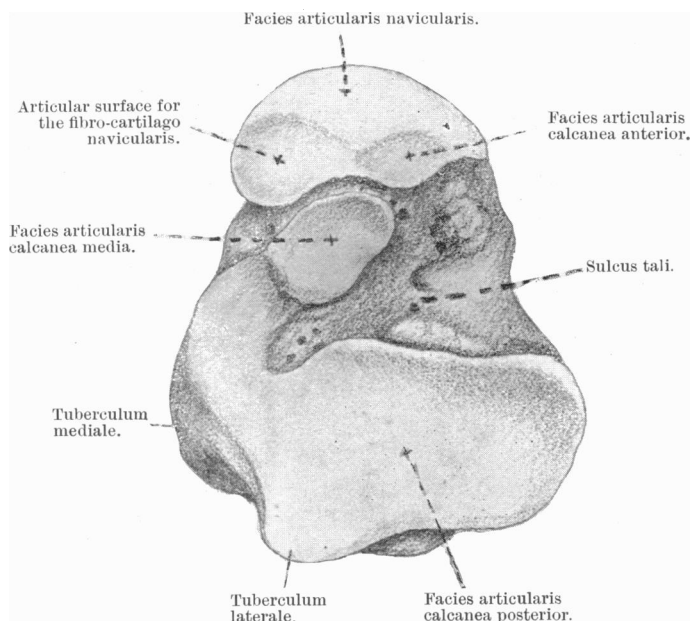


FIG. 17.—*Norma basilaris*—showing fusion of facies articularis calcanea posterior with the facies inferior accessoria corporis tali. No. 974.

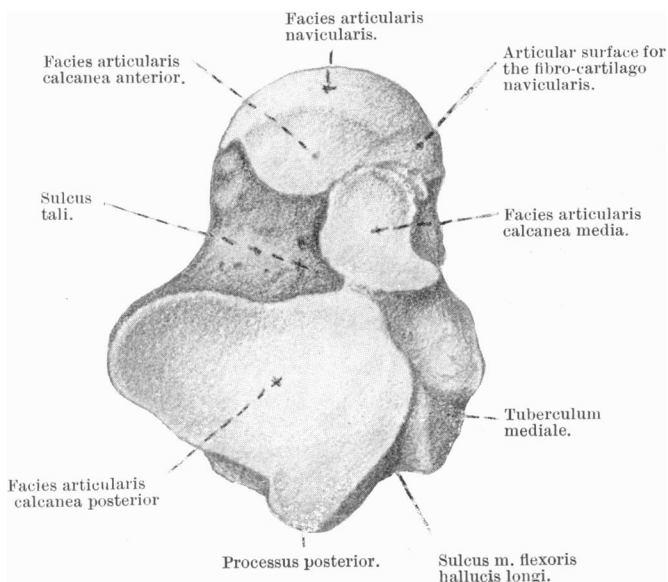


FIG. 18.—*Norma basilaris*—showing the junction of facies articulares calcaneæ media et posterior across the sulcus tali. No. 466.

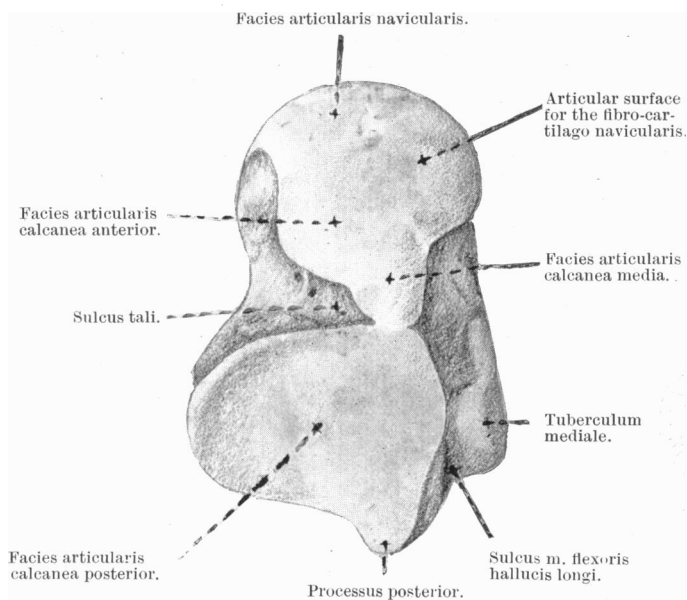


FIG. 19.—Norma basilaris—showing fusion of facies articulares calcaneæ posterior et media. No. 655.

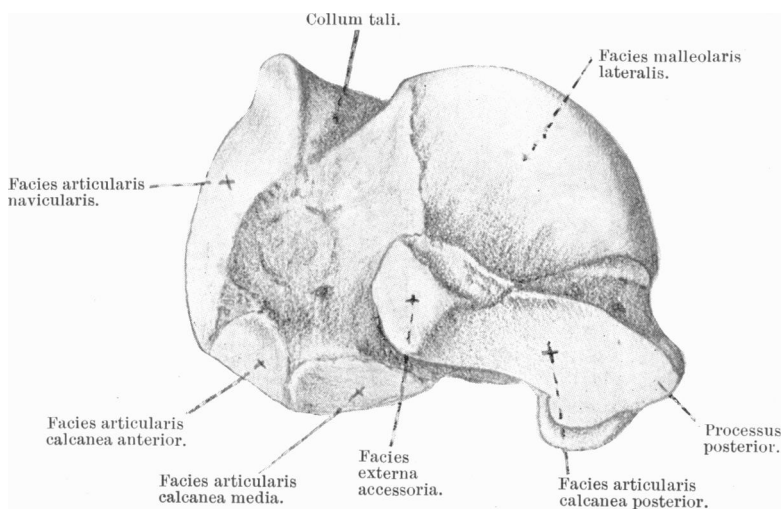


FIG. 20.—Norma lateralis—showing the facies externa accessoria corporis tali. No. 529.

LIST OF AUTHORS MOST OF WHOM ARE CITED
IN THE TEXT.

- (1) BARCLAY SMITH, E., "The Astragalo-calcaneo-navicular Joint," *Jour. of Anat. and Phys.*, vol. xxx., 1896, p. 390.
- (2) VON BARDELEBEN, "Das intermedium Tarsi beim Menschen," *Sitzungsberichte der jenaischen Gesellschaft für Medicin und Naturwiss.*, 1883, 2nd March, pp. 37, 39.
- (3) VON BARDELEBEN, "Ueber das intermedium Tarsi," *Sitzungsberichte der jenaischen Gesellschaft für Medicin und Naturwiss.*, 1883, 3rd June.
- (4) BENNETT, E. H., "On the Ossicle occasionally found on the Posterior Border of the Astragalus," *Jour. of Anat. and Phys.*, xx., 1887, pp. 59, 65.
- (5) BIANCHI, ST., "Sopra un raro caso di Os trigonum del Bardeleben," *Monitore Zoologico*, i., 1890, p. 171.
- (6) CHARLES, R. HAVELOCK, "Influence of Function as exemplified in the Morphology of the Lower Extremity of the Punjabi," *Jour. of Anat. and Phys.*, xxviii., pp. 1-18.
- (7) CLOQUET, "Bull. de la Société Anatomique de Paris," xx., 1844, p. 131.
- (8) FAWCETT, "Two Undescribed Facets on the Astragalus," *Edin. Med. Jour.*, 1895, May.
- (9) GRUBER, "Ueber einen am Malleolus externus artikulirenden Knochen," *Virchow's Archiv*, Bd. xxvii., 1863.
- (10) GRUBER, "Vorläufige Mittheilung über die secundären Fusswurzelknochen des Menschen," *Archiv für Anat. Phys. und Wiss. Med.*, 1864, pp. 286-290.
- (11) MANSELL MOULIN, C., "The Os trigonum of the Tarsus as a Source of Error in the Interpretation of Skiagraphs," *British Med. Jour.*, 1901, 1st Jan., p. 16.
- (12) PARKER and SHATTOCK, "The Pathology and Etiology of Congenital Club-foot," *Trans. of Patholog. Soc.*, vol. xxxv., 1884.
- (13) PFITZNER, W., "Beiträge zur Kenntniss des menschlichen Extremitatenskelets, vii.," *Morpholog. Arbeiten hrsg. v. G. Schwalbe*, iv., 1896, p. 245.
- (14) SHEPHERD, F. J., "A Hitherto Undescribed Fracture of the Astragalus," *Jour. of Anat. and Phys.*, xvii., 1883, p. 79; and in same *Journal*, vol. xxi., p. 335.
- (15) STIEDA, "Ueber sekundäre Fusswurzelknochen," *Archiv für Anat. Physiolog. Wiss. Med.*, 1869, s. 108.
- (16) STIEDA, "Der Talus und das Os trigonum Bardelebens beim Menschen," *Anatomischer Anzeiger*, iv., 1889, pp. 305-319, 336-351.
- (17) SUTTON, J. BLAND, "A Case of Secondary Astragalus," *Journ. of Anat. and Phys.*, vol. xxi., p. 333.

(18) THILENIUS, G., "Das Os intermedium antebrachii des Menschen," *Morphologische Arbeiten*, v., 1895, pp. 1-16.

(19) THOMSON, A., "Report of the Committee of Collective Investigation of the Anatomical Society of Great Britain and Ireland for the Year 1889-90," *Jour. of Anat. and Phys.*, xxv., 1891, p. 98.

(20) TURNER, WM., "A Secondary Astragalus," *Journ. Anat. and Phys.*, vol. xvii., p. 82, and vol. xxi., p. 334.

(21) VIRCHOW, "Das Skelett eines verkrüppelten Chinesinnes Fusses," *Zeitschrift für Ethnologie*, 35 Jahrgang, 1903.